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Impact of Iron Ore Mining: Comparison of Physicochemical Parameters and Heavy Metals in Upstream and Downstream Sites of a River

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ABSTRACT

Mining activity in Goa has created a degraded environment and is a matter of great concern. Damage to the environment is mainly done by the reject dumps, pumping out of muddy waters and slimes from the beneficiation plant. The present study was designed to determine the physicochemical parameter status along the river in shigao-kalay area in South Goa, where iron ore mines are concentrated. Upstream site of the river was taken as a measure of uncontaminated site as compared to down stream site which had influx of mining effluents from the surrounding mines. Water samples were collected from both sites and evaluated for physicochemical parameters. The water in the uncontaminated upstream region was cooler, more clear and rich in oxygen as compared to downstream region. The downstream region showed higher concentration of sulphates, increased turbidity, temperature and decreased pH. Heavy metal analyses of the water samples from both the sites showed contamination of downstream site with iron, manganese and zinc, indicating the impact of degradation of water quality due to influx of mining effluents. Examination of the fishes from the upstream and downstream region revealed decrease in the body weight of the fishes in the downstream site as compared to the upstream site.

INTRODUCTION:

Mining is a major economic activity of Goa. The mining belt of Goa covers an area of approximately 700 sq.kms. The mine wastes constitute a potential source of contamination to the environment, as heavy metals and acid are released in large amounts (*Ledin M et al., 1996*). Both small and large-scale mining operations are inherently disruptive to the environment, producing enormous quantities of waste that can have deleterious impacts for decades. Mining in Goa is synonymous with Iron Ore Mining, over 60% of country's iron ore export is from Goa. Iron-Ore mining either by surface or underground methods have irreparable consequences on the environment (*Ameh E. G et al., 2011*). Mining activity in Goa has created a degraded environment and is a matter of great concern. Damage to the environment is mainly done by the reject dumps, pumping out of muddy waters from the working pits including those where the mining operations have gone below the water table, and slimes from the beneficiation plant. Aquatic pollutants from the mines may produce multiple consequences at organism, population, and community and ecosystem level, affecting organ function, reproductive status, population size, species survival and thus biodiversity. These effects may eventually alter the organism's ability to grow, reproduce, or even survive. Besides altering the physicochemical properties of water, mining activity is also contributing release of heavy metals through the effluents. The data available on the degradation of water bodies on account of mining in Goa is restricted. Therefore assessment of water quality around mining areas is essential as all aquatic organisms are directly or indirectly affected by the physical characteristics of their environment, especially the chemical composition of the water. All these measurable changes serve as indicators of pollutant stress. They provide early warnings of environmental damage. The site selected for the study is also of paramount importance as it is close to the 'Selaulim Dam' which is the main source of drinking water supply. The river water flowing through the 'Kalay' region in vicinity of some mines is used by the locals for the purpose of irrigation and domestic use including drinking. Sampling point which was located 4 km upstream of the mining area was meant to establish the water quality before the influence of mining activities. Therefore the present study was undertaken to determine the change in water quality on account of mining activity, by comparing the physicochemical parameters of water samples collected from upstream and downstream sites. We also evaluated the effect of change in water quality on the growth of fishes.

MATERIAL AND METHOD:

The area selected for the study was shigao-kalay area which is located in Sanguem taluka of South Goa. We identified two areas of a river, for our sample collection. Selection of sample area was based on the location of influx of effluents from the nearby prominent mines. The upstream and the downstream location of this river were considered for sample collection. Catch sampling method was used to compare the parameters in the upstream and downstream site. Sampling point which was located 4 km upstream of the mining area was meant to establish the water quality before the influence of mining activities. The 'upstream' region was thus considered to be a reflection of water condition devoid of mining effluents. The region after this location, we had seen effluents of the nearby mines getting poured in the water body. This Downstream site of the river was considered as the second area for sample collection as it may be considered as a study area with altered water quality on account of influx of mining effluents. Water samples and live fishes were collected from the upstream and downstream sites of the study area. Physicochemical parameters were analysed as per the SOPs of ITALAB, which is NABL accreditated. Parameters analysed were pH, turbidity, temperature, conductivity, biochemical oxygen demand, carbonates and bicarbonates, dissolved oxygen, phosphates, nitrates, sulphates and free carbon dioxide. Heavy metal analysis was done by atomic absorption spectrophotometer. Heavy metals tested included iron, manganese, arsenic, lead, zinc, mercury, copper and hexavalent chromium. The fishes collected from both the study sites were subjected to some morphological analysis which included body weight, breadth and length of fishes. The data was tabulated analysed statistically. The statistical significance of associations between various qualitative parameters was evaluated through Fisher's exect test(two tail). online calculators of statistic were used for standard deviation at *www.easycalculation.com* and fisher's test at *www.graphpad.com.*

RESULT:

In the present study the physicochemical parameters which were significantly altered in the downstream sample were turbidity and sulphates and heavy metal concentrations of manganese, zinc and iron. Factors which showed difference but were statistically insignificant included pH, conductivity, temperature, hardness, carbon dioxide, salinity, nitrates and BOD.

When the physiochemical parameters of the upstream waters were compared to the downstream site, there was remarkable difference observed. The present study showed that there was reduction in the pH of the water of downstream sample. The reduced pH rendered the water acidic as compared to the upstream sample. The turbidity of the downstream sample was increased to 13 NTU as compared to the upstream sample which had turbidity of 1.4 NTU *(Table 1).* The difference was found to be statistically highly significant *(P=0.0001)*. The downstream water was highly turbid as compared to the WHO permissible limits. Even conductivity, temperature, salinity and hardness of the downstream water were increased. The downstream waters were rendered warmer by 0.5° C. The salinity too was increased considerably. Nitrate and phosphate concentrations from both sites did not show much variation. However sulphate concentration in the water sample from downstream site was found to be significantly higher *(P=0.0062),* as compared to the upstream. BIS recommended 5.0 mg/L concentration of dissolved oxygen (DO). The DO of water samples from both sites was low. Free Carbon dioxide from both sites did not show significant variation. There was no significant variation in the concentration of aluminium in the upstream and downstream samples *(P=1.000).* BIS recommended that water bodies having above 3.0mg/l concentration of biochemical oxygen demand is not suitable for domestic use. The BOD of both the samples was quite low.

Table 1 about here

Pollution of water bodies with heavy metals can be one major problem on account of mining activity. The heavy metals detected in the downstream sample included iron, manganese, zinc, copper and hexavalent chromium. The concentration of iron, magnesium and zinc was significantly higher in the downstream sample as compared to upstream. The concentration of the heavy metals in the upstream and downstream site is tabulated in *Table 1*. The iron concentration was beyond desirable limits defined for drinking water by BIS.

Another remarkable feature that was noticed was drastic effect of these physicochemical changes on the growth of the fishes. The fish from the two sites were collected and examined for their body length, width and body weight. The fishes were identified as belonging to genus '*Puntius*'. The study revealed decrease in body length, breadth and weight of the fishes in the downstream waters. The average body length of the fishes in upstream site was 4.68 ±0.70cms with variance of 0.49. The average body length of fishes from downstream site was significantly reduced to 3.15 ± 0.45cms *(P=0.001),* with a variance of 0.205. The breadth of the body too was significantly reduced *(P= 0.0215).* We also observed drastic decrease in the body weight of the fishes in the downstream site as compared to the upstream site. The average body weight of the fishes from the upstream site was 1.245 ± 0.31 with a variance of 0.096 while the average body weight of fishes in the downstream was 0.461 ± 0.19cms with variance of 0.037. The reduction in body weight of the downstream fish was extremely statistically significant *(P= 0.0001).*

TABLE 1: COMPARISON OF THE PHYSICO-CHEMICAL PARAMETERS

	PARAMETERS	UP-STREAM	DOWN-STREAM	TEST METHOD
PHYSICAL	pH	6.98	6.87	IS 3025: Part 11: 1983, Reaffirmed 2012
	Turbidity	1.4 NTU	13.0 NTU	IS 3025: Part 10: 1984, Reaffirmed 2006
	Conductivity	52.14 µs	54.98 µs	IS 3025: Part 14: 1984, Reaffirmed 2006
	Temperature	27.0°C	27.5°C	IS 3025: Part 9: 1984, Reaffirmed 2006
CHEMICAL CONCENTRATION IN MG/LTR	Hardness as $CaCO_3$	14.00	13.00	IS 3025: Part 51: 2001
	Dissolved oxygen	7.50	8.40	IS 3025:Part 38: 1989,Re-affirmed 2009
	Free carbon dioxide	4.00	3.00	IS 3025: Part 61: 2008
	Salinity	22.45	28.86	IS 3025: Part 32: 1988, Reaffirmed 2009
	Sulphates as SO_4	1.93	2.90	IS 3025: Part 24: 1986, Reaffirmed 2009
	Nitrates as NO_3	0.18	0.24	APHA 21st Edition 4500 NO3 – B
	Phosphates as PO_4	BDL	BDL	IS 3025: Part 31: 1988, Reaffirmed 2009
	Aluminium as Al	0.02	0.02	IS 3025: Part 55: 2003, Reaffirmed 2009
	Bio-chemical oxygen demand	0.80	0.60	IS 3025: Part 44: 1993, Reaffirmed 2009
HEAVY METALS CONCENTRATION IN µG/LTR	Iron as Fe	150	340	IS 3025: Part 53: 2003
	Manganese as Mn	BDL	290	APHA No 3500 – Mn
	Zinc as Zn	BDL	90	IS 3025: Part 49: 1994, Reaffirmed 2003
	Copper as Cu	BDL	2	IS 3025: Part 42: 1992, Reaffirmed 2009
	Hexavalent Chromium as Cr^{+6}	BDL	5	IS 3025 Part 52 : 2003
	Arsenic as As	BDL	BDL	APHA 3114 B 22nd Edition
	Lead as Pb	BDL	BDL	IS 3025: Part 47: 1994, Reaffirmed 2003
	Cadmium as Cd	BDL	BDL	IS 3025: Part 41: 1992, Reaffirmed 1998
	Mercury as Hg	BDL	BDL	APHA 3112 B – 22nd Edition

BDL – below detectable level.

Since the physicochemical parameters which were significantly altered in the downstream sample were turbidity and sulphates, decrease in pH, increase in temperature, and increase in heavy metal concentrations of manganese, zinc and iron, we attribute the decrease in body size and weight of the fishes to the synergistic effect of stress posed by the physicochemical parameters as well as the an cumulative effect of the heavy metals.

DISCUSSION:

Water analysis of waters from upstream and downstream site revealed deterioration of the water quality at the downstream site. This is a clear indicating of the impact of degradation of water quality due to influx of mining effluents. This deterioration of water quality directly or indirectly affects the aquatic organisms.

Change in pH of water can affect the aquatic life. A neutral pH characterizes water where life develops in optimal way *(Bari laterza, 1995*). Low values in pH are indicative at high acidity, which can be caused by the deposition of acid forming substances in precipitation. The reduction in the pH of the downstream sample may be on acidic discharge from the mines especially Leachate from acids added during beneficiation processes. This water is also used for drinking purpose by the locals. Besides affecting the aquatic organisms lowered pH values less than 7.0 also corrode water pipes, which may result in the release of metals into drinking water. This can be toxic and may pose health problems if concentrations of such metals exceed recommended limits (*Anderson et al., 2000*). The most possible environmental impact of pH involves synergistic effects. Synergy involves the combination of 2 or more substances, which produce effects greater than their individual effect, for example; water with iron of a given concentration will become more toxic to fish as water becomes more acidic (*Annon, 2004*). The turbidity of the downstream sample was significantly increased to 13 NTU as compared to the upstream sample which had turbidity of 1.4 NTU. Turbidity in the water as well as an increase in chlorophyll also accompany accelerated algal growth and indicate increased eutrophication. Water temperature is also one of the most important physical characteristics of aquatic systems (*Deas and Lowny, 2000*). It is one of the most important regulators of life processes in aquatic ecosystems (*FOEN, 2011*). It has direct and indirect effects on nearly all aspects of stream ecology. Temperature also influences the rate of photosynthesis by algae and aquatic plants. As water temperature rises, the rate of photosynthesis increases thereby providing adequate amounts of nutrients (*Boulton, 20*12). Temperatures higher than 15°C favor the development of micro-organisms and activate chemical reactions (*Merzoug AN et al., 2012*). The increased water temperature in the downstram, may favour growth of organisms initially, but may subsequently have a negative effect on account of multiple factors working against the growth of organisms. The DO of water samples from both sites were within the permissible limits. This indicates that there is no much decomposition of organic matter, as Oxygen is rapidly depleted from this thin layer mostly as a result of decomposition of organic matter *(Kiyani V et al., 2013)*. We did not observe significant variation in the concentration of free carbon dioxide, salinity, nitrates and phosphates in the water samples of the selected sites. Some studies have reported Toxicity of nitrate (*William M., L. J, 1986; Camargo JA, 2005*). Nitrite toxicity is exacerbated by low oxygen concentrations because nitrite reduces the oxygen-carrying capacity of the blood. Since we did not find alteration in the nitrate concentration the toxicity ob account of Nitrates can be ruled out. However the present study showed significantly higher concentration of sulphates in the water sample from downstream site as compared to the upstream. Higher concentration of sulphates is a matter of concern as this water is also used by locals for the purpose of drinking. General population may be at greater risk from the laxative effects of sulfate when they experience an abrupt change from drinking water with low sulfate concentrations to drinking water with high sulfate concentrations. Sulphate salts may also increase the corrosive properties of water. The present there is decreased pH, increased sulphates, increased turbidity and heavy metals indicating that the source of contamination is 'Acid mine drainage' from the mines. Acid mine drainage is considered one of mining's most serious threats to water resources. A mine with acid mine drainage has the potential for long-term devastating impacts on rivers, streams and aquatic life.

The present study also revealed that the downstream site had higher concentration of heavy metals. The heavy metals detected in the downstream sample included iron, manganese, zinc, copper and hexavalent chromium. Though the concentration of these metals was less, its influence is of utmost importance because heavy metals can be acutely toxic in relatively small amounts and injurious through long-term (chronic) exposure in minute concentrations. They have the potential to increase the risk of cancer, birth defects and genetic mutations through long-term, low-level exposure. The source for entry of these heavy metals in the downstream site is mostly through the surface runoff. The heavy metal analysis of the present study shows increase in the concentration of iron in the downstream site and presence of manganese zinc and chromium in the downstream site. Iron (Fe) is essential for life, being involved in oxygen transfer, respiratory chain reactions, DNA synthesis, and immune function. However in high concentration it can be deleterious as physiological evidence indicates that iron preferentially crosses the apical membrane of both the gills and intestine in the ferrous (Fe^{2+}) state. Manganese excess may cause a Ca^{2+} pump dysfunction, affecting neuro-muscular transmission in benthic marine invertebrates (*Hagiwara & Takahashi, 1967; Baden & Neil, 1998; Holmes et al., 1999, Perl & Olanow, 2007*). This neurodegenerative disorder is due to the accumulation of manganese inside intracellular compartments, such as the Golgi apparatus and mitochondria. In mammals, prenatal and postnatal exposure to manganese is associated with embryo-toxicity, fetal-toxicity and decreased postnatal growth (*Sanchez et al., 1993*). Therefore increase in manganese concentration in the present study is a matter of concern. At high concentration levels, heavy metals accumulate in different organs, damage tissues and interfere with the normal growth and proliferation (*Alkarkhi et al., 2009*). That is why knowledge regarding the toxicity of heavy metals to aquatic organisms is of paramount importance (*Rathore and Khangarot, 2003*).

Thus, reduction in the body size and weight of the fishes in the downstream site of the present study can be attributed to the influx of heavy metal via the mining effluents and also due to the change in the water quality. The change in water quality may be acting as a severe stress factor impeding the growth of the fishes. Many studies were carried out on different species and revealed that both essential and non-essential metals cause toxic effects in fish through disturbing the physiological activities, biochemical processes, reproduction and growth and finally lead to their mortality *(Hanan, 2007)*. Therefore we infer that increase in the heavy metal concentration may be a possible cause of reduction in body weight of fishes from the downstream site

CONCLUSION:
Synergistic effect of change in water quality and increase in heavy metal concentration in the downstream region on account of mining may be the possible cause of impaired growth of fishes indicated by reduction in body length and weight of the fishes. Though increase in each of the physicochemical factor is low, the interplay of all factors in totality can impose severe stress on the body metabolism of the fishes, thereby acting as an impediment for body growth. The present study is a small reflection of the consequences of environmental degradation; the large picture encompasses the damage to air, water and land. For sustainable development we need mining activities to be carried out without depleting the natural resources. For the sake of current and future generations we need to safeguard the purity and quantity of our water against irresponsible mineral development.

FIGURE 1: INDICATING IMPAIRED GROWTH IN FISHES FROM DOWNSTREAM SITE

Puntius narayani collected from upstream and downstrem region near Kalay area.

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